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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Regulating System for Dividing a Stream of Fluid into at least Two Subsidiar y Streams

WE, SULZER FRERES, SOCIETE ANONYME, a Company organised under the laws of Switzerland, of Winterthur, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a regulating system for dividing a stream of fluid into at least two subsidiary streams by means of throttling elements which influence the flows in the subsidiary streams. It is an object of the invention to provide such a system in which at least one of the throttling elements is always fully open, in order to keep throttling losses as low as possible. The division may be effected in accordance with any desired laws such as arise from the particular case of application of the invention. The invention thus relates to a regulating system for dividing a stream of fluid into at least two subsidiary streams, wherein each conduit carrying a subsidiary stream contains a throttling element with a regulator therefor and wherein at least one of the throttling elements is always fully open.

According to the invention there is fed to the input of each regulator a signal which is dependent on a regulated value that is in turn dependent on the flow of the associated subsidiary stream, and a desired value signal which is dependent in part on a desired proportion of the sum of the signals dependent on the regulated values and in part on an adjusting signal applied to the fully open throttling element from the associated regulator.

By way of example, the invention can be applied to the division of the total quantity of water delivered from a well among a plurality of consumers connected to the well, the regulating system embodying the invention ensuring that each consumer receives a specified proportion of the total quantity even if an attempt is made to give one of the consumers more than the proportion due to that consumer, for example by lowering the back pressure in the conduit which supplies this consumer. The invention can also be applied, for example, if a stream of a medium is to be distributed among a plurality of heat-exchangers in such manner that the subsidiary streams leaving the heat exchangers have equal temperatures or certain temperature differences in relation to one another. The medium may be a medium that is to be heated in the heat exchangers or a medium which is to give up heat to another medium. Examples occur in certain types of nuclear reactors.

The regulating system according to the invention can also be used in steam generators, for example in conjunction with a superheater arrangement which has a number of parallel-connected heating surfaces and in which the superheating end temperature is regulated by water injection. In this case, the regulating system can be so modified that the amount of steam to be supplied to each heating surface is so adjusted that the injection water quantities of each heating surface are equal to one another.

"Fully open" in this specification includes the case where the throttling element has a flow cross-section somewhat smaller than the maximum, the spindle of the throttling element being not quite at the end of its travel so that it can move at least slightly in either direction. This has a favourable effect in as much as if a disturbance occurs in the plant the shunting of the regulating system dies away more rapidly than would be the case if the fully open throttling element were right at the end of its travel.

The invention may be performed in vari-

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ous ways, and some specific embodiments will now be described by way of example with reference to the accompanying drawings, in which

Figure 1 diagrammatically shows a regulating system embodying the invention which distributes in such manner that the same quantity flows through each conduit ;

Figure 2 diagrammatically illustrates a modification of the regulating system shown in Figure 1 ;

Figure 3 illustrates an actual embodiment of a regulating system similar to that shown in Figure 1, the quantities flowing through the component conduits being adjustable ;

Figure 4 shows an actual embodiment of a regulating system which divides a stream of a medium in such manner that the temperatures of the subsidiary stream flows are equal to one another ;

Figures 5 and 6 show modifications of the regulating system according to Figure 4 ; and

Figure 7 diagrammatically illustrates a regulating system in conjunction with the superheater arrangement of a steam generator.

According to Figure 1, a stream of a fluid medium, for example water from a well, is delivered through a conduit 1 which divides into three subsidiary conduits 2, 2′ and 2″. Each of the three subsidiary conduits contains a throttling element 5, 5′ and 5″ respectively, and a restrictor 6, 6′ and 6″, respectively, the latter being disposed downstream of the throttling elements. The reference numerals 5, 5′ and 5″ respectively, at the same time denote the servomotor (not shown in detail) belonging to the throttling element. A flow signal transmitter 7, 7′ and 7″ respectively is associated with each restrictor and is connected to its associated restrictor by way of pressure lines 3, 3′ and 3″ respectively ; for the sake of simplicity, only one of the two pressure lines leading from the restrictor to the flow signal transmitter is shown in each case. From each flow signal transmitter a signal line 8, 8′ and 8″, respectively, leads to a regulator 9, 9′ and 9″ respectively, which has a proportional-integral (PI) characteristic. The output signal of each regulator is delivered by a signal line 18, 18′ and 18″, respectively, to the servo-motor operating the throttling element 5, 5′ and 5″ respectively.

In addition to the signal line 8, 8′ and 8″, a signal line 10, 10′ and 10″, respectively, leads from each flow signal transmitter 7, 7′ and 7″ respectively, to a signal collector line 11. The collector line 11 leads to a proportional averaging unit 13, in which the arithmetic mean is formed from the sum of the signals delivered by the flow signal transmitters. The output of the averaging unit 13, is delivered by a signal line 15 to an addition point 16. A signal line 4 leads away from the addition point, and from this line there branch off three desired value signal lines 17, 17′ and 17″, which lead to the desired value inputs of the regulators 9, 9′ and 9″ respectively.

A line 19, 19′ and 19″, respectively, branches from the signal line 18, 18′ and 18″ respectively, and leads to a selector unit 22. From the output side of the selector unit 22 a signal line 23 leads to a point 24 which is connected by a signal line 26 to the addition point 16 and receives a desired value from a transmitter (not shown) via a signal line 25.

The regulating system according to Figure 1 adjusts the amounts flowing through each of the three subsidiary conduits 2, 2′ and 2″ in such manner that these quantities are always equal to one another even if someone tries to obtain more medium than the proportion due to him, by lowering the back pressure in the subsidiary conduit wflhich supplies him. Moreover, one of the throttling elements 5, 5′ and 5″ is always fully open. Assuming that the throttling element 5′ is fully open and somebody attempts to obtain more medium by lowering the back pressure in the subsidiary conduit 2, for example by opening a valve (not shown), then the regulating system illustrated operates in the following way. In the first instance, a greater quantity of medium flows through the restrictor 6 owing to the reduced back pressure in the subsidiary conduit 2, and this produces a greater pressure drop across the restrictor. In accordance with the greater pressure drop, the flow signal transmitter 7 transmits an increased signal through the lines 8 and 10 ; for example, the value of the increase may be assumed to be three units. Assuming that correspondingly more medium flows in through the conduit 1, the sum of the flow signals fed to the proportional averaging unit 13 thus also increases by three units. As a result of the mean-value determination by the unit 13, the output signal of the latter is one unit larger than previously, so that the lines 17, 17′ and 17″ feed to each of the three regulators 9, 9′ and 9″ a desired value higher by one unit. The flow signal which is supplied by way of the line 8 and which is larger by three units is now compared in the regulator 9 with the desired value signal which is larger by one unit, and an adjusting signal reduced by two units is fed to the servometer of the throttling element 5, which closes accordingly. In the regulators 9′ and 9″ it would be necessary for the adjusting signals for the lines 18′ and 18″ to be increased by one unit in accordance with the comparison between the signals which have remained substantially constant in the lines 8′ and 8″ on the one hand

and the desired value signals which are larger ,by one unit in the lines 17′ and 17″ on the other hand, and this increase of the adjusting signal by one unit would mean an increase of the flow cross-section of the throttling elements 5′ and 5″. Since, however, the throttling element 5′ is already fully open and cannot therefore open further, the increased adjusting signal in the line 18′ acts through the line 19′ on the selector unit 22 which accordingly feeds a larger signal through the line 23 to the point 24. Since this signal is greater than the desired value signal fed in by the line 25, a negative signal occurs in the line 26 which reduces the desired value signal in the line 4 until the signal in the line 23 again corresponds to the desired value signal in the line 25. This means that no change occurs at the throttling elements 5′ and 5″ and that the flow cross-section of the throttling element 5 is reduced further.

Assuming, starting from the state of equilibrium, that the throttling element 5 is fully open and that the attempt is made to draw off more medium by reducing the pressure in the subsidiary conduit 2, then in the same way as with the previous assumption as a result of the larger flow signal in the line 10 a larger signal sum is fed to the proportional averaging unit 13 and a larger desired value signal corresponding to the new mean value is fed through the line 17, 17′ and 17″ to the regulators 9, 9′ and 9″. The flow cross-section of the throttling element 5 is reduced accordingly and the flow cross-sections of the throttling elements 5′ and 5″ are increased. In this case, as a result of the reduced signal in the line 19, a deviation occurs between the signal in the line 23 and the desired value signal in the line 25 — if the adjusting signals in the lines 18′ and 18″ remain smaller than the reduced adjusting signal in the line 18 — and this increases the signal in the line 26. In consequence, the desired value signal originating from the addition point 16 is increased in the lines 4, 17, 17′ and 17″ until the signal in the line 23 and the desired value signal in the line 25 are again equal. The increased desired value signals in the lines 17, 17′ and 17″ thus have the effect that the throttling element 5 opens fully again while the throttling elements 5′ and 5″ open until the quantities flowing through the subsidiary conduits 2, 2′ and 2″ are again equal to one another.

With this regulating system it is thus possible at any time to make the quantities flowing through each of the subsidiary conduits equal to one another, one of the throttling elements always being fully open, irrespective of which of the three subsidiary conduits is subjected to an attempt to obtain more medium by back pressure reduction and which of the three throttling elements is fully open.

In the embodiment shown in Figure 2 the regulating system is modified in that, instead of the signal lines 10, 10′ and 10″ and 11 leading from the flow signal transmitters 7, 7′ and 7″ to the proportional averaging unit 13, one signal line 90 is provided which leads from a flow signal transmitter 91 connected by pressure lines 92 to a resistor 93 in the conduit 1. In this case, therefore, the total flow through the conduit 1 is measured and fed to the proportional unit 13 for the formation of the mean value. The mode of operation of the regulating system is the same in principle as that of the system shown in Figure 1. Assuming that an attempt is made at the subsidiary conduit 2 to obtain more medium by back pressure reduction and the throttling element 5′ is fully open and the same quantity as previously flows through the conduit 1 independently of the back pressure reduction in the subsidiary conduit 2, the following regulating cycle takes place. The increased flow of medium in the subsidiary conduit 2 is detected by the restrictor 6, so that the flow signal transmitter 7 transmits a larger signal to the regulator 9; for example, the increase may be assumed to equal two units. At the same time, smaller quantities of medium than previously flow through the subsidiary conduits 2′ and 2″ so that the flow signal transmitters 7′ and 7″ deliver smaller signals to the regulators 9′ and 9″; the reduction may be assumed to equal one unit in each case. In accordance with the altered flow signals, the flow cross-section of the throttling element 5 is reduced by two units, while the flow cross-section of each of the throttling elements 5′ and 5″ would have to be increased by one unit. Since the throttling element 5′ is already fully open, the command given by the regulators 9′ and 9″ cannot be performed. The larger adjusting signal in the line 18′ is fed by the line 19′ to the selector unit 22 which accordingly delivers a larger signal to the line 23, this signal being larger than the desired value signal in the line 25. A negative signal is thus transmitted through the line 26 and results in a reduction of the desired value signals in the lines 17, 17′ and 17″. The reduced desired value signal in the line 17 varies the adjusting signal in the line 18 by way of the regulator 9 in such manner that the throttling element 5 closes still further. The adjusting signals in the lines 18′ and 18″ resume their original value as a result of the reduced desired value signals in the lines 17′ and 17″, so that the throttling elements 5′ and 5″ retain the original flow cross-section. Mutually equal quantities thus again flow through the three subsidiary conduits.

Figure 3 shows an actual embodiment of a similar system to the regulating system in Figure 1, the said embodiment making use of electrical components. A difference from Figure 1 in this case is that the flows of the subsidiary streams may differ from one another, an adjustable ratio between these flows being maintained. A supply conduit 51 branches into three subsidiary conduits 52, 52′ and 52″, each containing a throttling element 55, 55′ and 55″, respectively. Each subsidiary conduit also contains a restrictor 56, 56′ and 56″, connected by signal lines 53, 53′ and 53″, respectively, to an electrical flow signal transmitter 57, 57′ and 57″, respectively. From each flow signal transmitter a conductor 30, 30′ and 30″, respectively, leads to a PI regulator 59, 59′ and 59″, respectively, and a conductor 31, 31′ and 31″, respectively, leads to a terminal of a potentiometer formed by rheostats 35, 35′ and 35″. The primary winding of a transformer 32, 32′ and 32″, respectively, is connected to each pair of conductors 30, 31; 30′, 31′ and 30″, 31″. The secondary windings of the three transformers are connected in series in a conductor 33, and the three rheostats 35, 35′ and 35″ are connected in series in a conductor 34. A conductor 36, 36′ and 36″, respectively, leads as second conductor from the other terminal of each potentiometer to the PI regulator 59, 59′ and 59″, respectively. With the arrangement described thus far, in each case a voltage proportional to the flow as the regulated value, is compared with the voltage at the associated rheostat as the desired value, and the deviation between the two is fed as an input voltage between the conductors 36, 30; 36′, 30′; 36″, 30″, respectively, to the associated regulator. For the sake of simplicity, only the left-hand regulator 59 and associated components will be described in detail. The constructions of the other two regulators and associated components are identical, and the corresponding parts are given the same reference numerals, single primed or double primed as the case may be.

The regulator 59 is constructed in a known manner. The conductor 30 and a conductor 37 branching off from the conductor 36 are connected in the usual way to the driver coil of a Ferraris induction motor 41, the driving pinion 42 of which rotates at a speed corresponding to the input voltage. The pinion 42 adjusts the movable coil 38 of an inductive transmitter by way of a rack 43, the fixed coils 39 of this inductive transmitter being maintained at a reference alternating-current voltage E. The coil 38 is connected in series in a conductor 44 branching off from the conductor 30, and the voltage induced in it is dependent on the position of the coil 38 and hence on the period of time during which a voltage acts on the driver coil of the motor 41. The voltage of the coil 38 provides the time integral of the input voltage at the driver coil and it is superimposed on the input voltage also acting at the conductors 36 and 44, and forming the proportional component. The output voltage of the regulator at the conductors 36 and 44 resulting from this conversion and forming an adjusting signal for the throttling element 55 is fed to an amplifier 40, the output voltage of which is fed to the driver coil of a servomotor 45 which is constructed on the same principle as the induction motor 41. The pinion 46 of the servo motor 45 drives a rack 47 which adjusts the flow cross-section of the throttling element 55. The rack 47 is connected to the movable coil 48 of an inductive transmitter the fixed coils 49 of which are at the reference alternating-current voltage E. Depending on the position of the rack 47 and hence of the coil 48 a voltage is induced in the latter and by way of a pair conductors 66 is fed to the input side of the amplifier 40 in opposition to the output voltage of the regulator 49; this circuit of the coils 48 acts as a feed-back system. The rack 47 has a collar 85 which is disposed between two stops 86 and 87 situated in the path of motion of this collar. The stops 86 and 87 thus limit the maximum and minimum flow cross-section of the throttling element 55.

On the output side of the regulator 59 a pair of conductors 69 is connected to the conductors 36 and 44 and leads to the primary winding of a transformer 72, which is part of a selector unit which passes only the highest output signal of the three regulators 59, 59′, and 59″. To this end, the secondary winding of the transformer 72 is connected by diodes 79 or other rectifiers to the primary winding of a transformer 80, to which the secondary windings of the transformers 72′ and 72″ are also connected in parallel, with the interposition of rectifiers 79′ and 79″respectively; the centre tapping of these coils is without a rectifier. The secondary winding of the transformer 80 is connected on the one hand to the conductor 34 and on the other hand, through two fixed coils 83 of an inductive desired value transmitter 75, to the conductor 33. The movable coil 82 of the desired value transmitter 75 is at the reference alternating-current voltage E and is connected to a manually operated spindle 84 by means of which it is thus possible to vary the voltage between the conductors 33 and 34; the voltage induced in the coils 83 represents the desired value for the maximum voltage passed by the rectifiers 79, 79′ and 79″, respectively from the secondary windings of the transformers 72, 72′ and 72″, respectively, and hence also the desired value for the maximum flow cross-section

of opening. The spindle 84 is generally operated only on the setting-up of the plant. When only a limited quantity of medium can be supplied through the conduit 1 — for example to protect a well from drying up — then adjustment of the spindle 84 may occur. In such a case, adjustment of the spindle is effected in such manner that the voltage induced in the coils 83 is reduced and hence also the maximum flow cross-section of the throttling elements 55, 55′ and 55″ is reduced.

The regulating system shown in Figure 3 operates in principle in the same way as the sysetm shown in Figure 1. Unlike Figure 1, however, the quantities flowing through the subsidiary conduits need not be equal to one another but may have a different and adjustable ratio. By way of example, the quantities flowing through the subsidiary conduits 52, 52′ and 52″ could be in the ratio of 1 : 2 : 3. This ratio of the subsidiary quantities is set at the potentiometer formed by the rheostats 35, 35′ and 35″. Any other desired ratios could be achieved in a similar manner.

If — as shown in Figure 3 — the throttling element 55′ is fully open, and assuming that an attempt is made to obtain more medium at the subsidiary conduit 52 by back pressure reduction, then the flow signal transmitter 57 delivers a larger voltage signal in accordance with the greater quantity of medium flowing through this subsidiary conduit. This larger voltage signal increases the input voltage to the regulator 59, the said input voltage representing the deviation of the actual flow from the desired value, and the regulator 59 then delivers as an adjusting signal to the amplifier 40 an output voltage which is smaller than previously and which acts in such manner that the servomotor 45 moves the rack 47 to the right, thereby reducing the flow cross-section of the throttling element 55. The displacement of the rack 47 continues until the voltage which is delivered by the coil 48 and is fed back to the amplifier 40 by way of the pair of conductors 66 in opposition to the output voltage of the regulator 59, is equal to the output voltage. The increased voltage at the flow signal transmitter 57 acts at the same time through the conductor 33 as a disturbance upon the components of the regulating system belonging to the other two subsidiary conduits 52′ and 52″. Since this disturbance changes the desired ratio of the subsidiary flow, the input voltages at the regulators 59′ and 59″ also vary in such manner that in each case a larger output voltage is delivered than previously, which would enlarge the flow cross-section of the throttling elements 55′ and 55″ by way of the servomotors 45′ and 45″. Since, however, the throttling element 55′ is already fully open, as will be seen from the position of the collar 85′ at the left-hand stop 86′, the servomotors 45′ cannot execute this command. The increased output signal of the regulator 59′ is fed via a pair of conductors 69′ to the transformer 72′ and thence to the transformer 80, with the result that the voltage in the circuit formed by the conductors 33 and 34, the 35′ and 35″, the secondary windings of the potentiometer formed by the rheostats 35, transformers 32, 32′ and 32″, the fixed coils 83 of the desired value transmitter 75 and the secondary winding of the transformer 80, is varied in such manner that the flow cross-section of the throttling element 55 is further reduced by the regulator 59 until the ratio of the subsidiary flows as set at the potentiometers 35, 35′ and 35″ is restored.

Consider now the case in which the throttling element 55 is fully open and the ratio of the subsidiary flows to one another is varied so that the subsidiary conduit 52 has to deliver a larger quantity than previously. A higher resistance is set at the rheostat 35 so that the input voltage to the regulator 59 is increased and at the same time the input voltage to the regulators 59′ and 59″ is reduced, because the rheostat 35 now receives a larger proportion of the total voltage which has remained constant and which is collected at the potentiometer formed by the rheostats 35, 35′, 35″. Owing to the higher input voltage to the regulator 59, its output voltage also becomes higher, and should increase the flow cross-section of the throttling element 55 by means of the servomotor 45. This is not possible, however, since the collar 85 is situated at the stop 86. Meanwhile, the flow cross-section of the throttling elements 55′ and 55″ is reduced as a result of the smaller input voltages and hence the smaller output voltages of their respective regulators 59′ 59″. The higher output voltage of the regulator 59 is fed to the transformer 72 by way of the pair of conductors 69, so that there is induced in the secondary winding of the transformer 80 a voltage which opposes the voltage induced in the secondary windings of the transformers 32, 32′ and 32″, so that the input voltages to the three regulators are reduced in such manner that its new output voltage corresponds to the fully open condition of the throttling element 55 while the lower input voltages to the regulators 59′ and 59″ influence the throttling elements 55′ and 55″ in such manner as further to reduce their flow cross-sections until the flows through the subsidiary conduits 52, 52′ and 52″ correspond to the new ratio set by the rheostats.

Assuming that the throttling element 55′ is fully open and the resistance at the rheostat 35 is increased, so that the flow through

the subsidiary conduit 52 increases, then the following regulating operation takes place. The input voltage to the regulator 59 is increased, while the input voltages to the regulators 59′ and 59″ are reduced, as in the previous case. Accordingly, the output voltage of the regulator 59 increases and the output voltages of the regulators 59′ and 59″ decrease. In consequence, the throttling element 55 opens while the throttling elements 55′ and 55″ begin to close. The smaller output voltage of the regulator 59′ produces a smaller voltage across the pair of conductors 69′, so that there is induced in the secondary winding of the transformer 80 a voltage which acts in the same sense as the voltage induced in the secondary windings of the transformers 32, 32′ and 32″. This increases the input voltage, and hence also the output voltage, of the regulator 59, the associated throttling element 55 of which opens at an accelerated rate, while the high input and output voltages of the regulators 59′ and 59″ delay the closing movement of the associated throttling elements 55′ and 55″ respectively. In the meantime, the voltage across the conductors 69 becomes larger than that across conductors 69′, so that the voltage induced in the secondary winding of the transformer 80 is reduced and finally disappears when the throttling element 55 is fully open.

Figure 4 shows a regulating system employing electrical components and wherein, instead of the flows through the subsidiary conduits, the temperature of each subsidiary stream of flowing medium is used to form the regulated value signal and the mean value of the temperatures of the subsidiary streams is used for the formation of the desired value. A conduit 131 carrying the medium to be distributed branches into three subsidiary conduits 132, 132′ and 132″. These subsidiary conduits contain throttling elements 133, 133′ and 133″, respectively. Part of each subsidiary conduit forms a heat-exchanger 134, 134′ and 134″, respectively, each subsidiary conduit being divided up into a group of parallel-connected tubes situated in a suitable region of a furnace where heat is received by the medium flowing through the tubes as is indicated by the arrows 135, 135′ and 135″, respectively. Downstream of each heat-exchanger 134, 134′ and 134″ an electrical resistance thermometer 136, 136′ and 136″ respectively, is provided which supplies the regulated value signal. Each of the resistance thermometers 136, 136′ and 136″ is connected in a from of bridge circuit with three resistances 137, 138, 139; 137′, 138′, 139′ and 137″, 138″, 139″, respectively. The resistances 136 and 137 are connected in series with a reference alternating-current voltage E, while the points a and b between the resistances 136 and 137 and between 138 and 139, respectively, are connected to the primary winding of a transformer 140. The secondary windings of the three transformres 140, 140′ and 140″ are connected in series in a conductor 141. The voltage between a and b; a' and b'; and a'' and b'' is proportional to the temperature of the medium flowing through the subsidiary conduits 132, 132′ and 132″, respectively and is compared with an opposing desired value voltage at the conductors 141 and 142 between the points c and d; c' and d'; and c'' and d, respectively. Any deviation resulting from this comparison is fed as an input voltage to a regulator 143, 143′ and 143″, respectively, which is constructed in the same way as the regulator 59 in Figure 3. The output voltage of the regulator 143 is fed to an amplifier 144 in the same way as in Figure 3, the said amplifier 144 being connected to a servomotor 145 which actuates the throttling elements 133 and the rack 146 of which is also connected to the movable coil 152 of an inductive transmitter, the said coil being connected by a pair of feedback conductors 147 to the input of the amplifier 144. The output voltage of the regulator 143 is fed by a pair of conductors 148 to the primary winding of a transformer 149 which in turn constitutes part of a selector unit and the secondary winding of which is connected by diodes or other rectifiers to a transformer 150 corresponding to the transformer 80 in Figure 3. The conductors 141 and 142 are connected to a transmitter 151 corresponding to the desired value transmitter 75 in Figure 3.

The operation of the regulating system shown in Figure 4 is such that the quantities of medium flowing through the subsidiary conduits 132, 132′ and 132″ are always so adjusted that mutually equal temperatures occur downstream of the heat-exchangers 134, 134′ and 134″ and at the same time one of the throttling elements 133, 133′ and 133″ is always fully open. If, for example, the throttling element 133 is fully open and if the heating 135 is intensified so that the temperature of the medium emerging from the heat-exchanger 134 rises in relation to the temperature of the medium emerging from the heat-exchangers 134′ and 134″, the regulator 143 receives a larger voltage corresponding to the greater deviation between the regulated value and the desired value. At the same time, the desired value voltage at the points c' and d' and c'' and d'' is reduced so that the regulators 143′ and 143″ receive a smaller voltage, since the voltage at the points a', b' and a'', b'' has remained constant. The higher output voltage of the regulator 143 and the smaller output voltage of the regulators 143′ and 143″ are fed to the amplifiers 144, 144′ and 144″, respec-

tively. The output voltages of the amplifiers 144′ and 144″ influence the servomotors 145′ and 145″ in such manner that the flow cross-section of the throttling elements 133′ and 133″ is reduced. The output voltage of the amplifier 144 should influence the servomotor 145 in such manner that the flow cross-section of the throttling element 133 is increased, but this does not occur because this throttling element is already fully open. The higher output voltage of the regulator 143 now acts through the pair of conductors 148 on the transformer 149 so that there is induced in the secondary winding of the transformer 150 a voltage which opposes the voltage induced in the secondary windings of the transformers 140, 140′ and 140″ and which further reduces the voltage between *c*, *d*; *c′*, *d′*; and *c″*, *d″*. This reduced desired value voltage results in a smaller input voltage at the regulators 143′ and 143″ and this accordingly has the effect of producing a smaller adjusting voltage from these regulators. The servomotors 145′ and 145″ are thus influenced by way of the amplifiers 144′ and 144″ in such manner that the flow cross-section of the throttling elements 133′ and 133″ is reduced further so that the supply of medium to the heat-exchangers 134′ and 134″ is reduced and hence the temperatures downstream of these heat-exchangers rise. These temperatures continue to rise until they are equal to the temperature downstream of the heat-exchanger 134. The throttling element 133 remains fully open in these circumstances.

While mutually equal temperatures are maintained with the regulating system shown in Figure 4, the modification of the regulating system shown in Figure 5 enables it to be used to maintain certain temperature differences between the individual subsidiary streams of medium. For the sake of simplicity, Figure 5 shows only the part of the system which differs from that shown in Figure 4, and then only in connection with the subsidiary conduit 132; the construction which is described hereinbelow is applied also to the other subsidiary conduits. The resistance thermometer 136 is again provided at the subsidiary conduit 132 and is connected to the three resistances 137, 138 and 139 to form a bridge circuit. The resistances 136 and 137 are in series with the reference alternating-current voltage E and the point *b* is connected to one end of the primary winding of the transformer 140. Between the other end of the primary winding of the transformer 140 (point *e*) and the point *a* the fixed coils 155 of an inductive transmitter 156 are now connected. The movable coil 157 of the transmitter 156 is connected to a manually operated spindle 158 and is at the reference alternating-current voltage E. The voltage which is induced in the coils 155 may be influenced by moving the coil 157 and may be positive or negative according to the position of the coil 157. The voltage at the points *a* and *b* which is dependent on the temperature at the resistance thermometer 136, is increased or reduced by this voltage. A false temperature is thus simulated between the points *b* and *e* and compared with the desired value between *c* and *d* so that the input voltage of the regulator 143 varies as a result, so that in the event of a temperature increase at 136 and given a positive voltage delivered by the transmitter 156 the associated throttling element 133 (not shown) opens to a greater degree than if the true temperature measured by the resistance thermometer 136 were operative. The temperature of the medium thus drops more than it would do without the influence of the additional voltage of the transmitter 156. With this arrangement it is thus possible, for example, for the medium at 136 to have a temperature lower by 20°C. than the medium at 136′ and for the latter to have a temperature lower by 20°C. than the medium at 136″. In this case the transmitter 156′ is set to a voltage of zero while the transmitter 156 is set to a positive supplementary voltage and the transmitter 156′ to a negative supplementary voltage equal to the positive supplementary voltage. In other respects the regulating operation of the system takes place in the same way as was explained for the embodiment shown in Figure 4.

The modification shown in Figure 6 is provided to prevent the temperature dropping below a certain value, in the case of regulating systems according to Figure 4 or Figure 5. For the sake of simplicity, Figure 6 shows only the subsidiary conduits 132 and 132′, with the associated regulators, of the system according to Figure 4, and, in addition, the modification for preventing the temperature from dropping. In Figure 6, the desired value transmitter 151 of Figure 4 is replaced by a desired value transmitter 160. A movable coil 161 is connected in series in the conductor 141 and is connected to a rack 162 of a servomotor 163. A manually operated spindle 164 is provided at the end of the coil 161 remote from the rack. The fixed coils 165 are at the reference alternating-current voltage E. A pair of conductors 166 is connected to the points *f* and *g*, which are at a voltage corresponding to the sum of the three temperatures measured, and the said pair of conductors 166 is connected to the input of an amplifier 167, the output of which is connected to the servomotor 163. The amplifier 167 also receives by way of a pair of conductors 168 a voltage representing the desired value for the minimum temperature. This voltage comes from a desired value transmitter (not

shown) constructed in the same way as the desired value transmitter 151 in Figure 4.

When the voltage at the pair of conductors 166 is higher than the desired value voltage at the pair of conductors 168, the movable coil 161 bears against the spindle 164 and the regulating system operates in the same way as explained in connection with the regulating system according to Figure 4. The spindle 164, which is operated only on the setting-up of the plant, is so adjusted that in this position of the coil 161 the voltage induced in it permits the maximum flow cross-section of the throttling elements 133, 133′ 133″. If, on the other hand, the voltage at the pair of conductors 166 becomes lower than the desired value voltage at the pair of conductors 168, the servomotor 163 begins to rotate in the anti-clockwise direction and moves the movable coil 161 to the left. As a result, the induced voltage in the coil 161 is reduced and hence the maximum flow cross-section of the throttling elements is also reduced. With this state of operation of the plant one of the throttling elements 133, 133′ and 133″ is always more fully open than the other two, but its point of maximum opening is so limited that the temperature at 136, 136′ and 136″ does not fall below the minimum temperature determined by the voltage at the pair of conductors 168. In these conditions a smaller amount of medium than previously flows through the subsidiary conduits 132, 132′ and 132″ so that the temperature again rises downstream of the heat-exchangers 134, 134′ and 134″. When the voltage in the pair of conductors 166 again becomes greater than the desired value voltage in the pair of conductors 168, the servomotor 163 moves the coil 161 to the right so that the maximum flow cross-section of opening of the throttling elements again increases with the increasing voltage in this coil.

In the regulating system shown in Figure 7, steam is fed through a header 201 from an evaporator (not shown) to the superheater section of a steam generator. To this end, the header 201 divides into four subsidiary conduits 202, 202′, 202″, 202‴, each of which is provided with a throttling element 203, 203′, 203″, 203‴, respectively. Each of the four subsidiary conduits includes the heater surfaces 204, 204′, 204″ and 204‴, respectively, of a first superheater, in which steam is superheated to an intermediate temperature. Each of the heater surfaces consists of tubes connected in parallel between inlet and outlet headers. After flowing through the heater surface 204, 304′, 204″, 204‴, respectively the steam passes through conduits 205, 205′, 205″ and 205‴, respectively, to the heater surfaces 206, 206′, 206″, 206‴, respectively, of a second superheater, in which the steam is superheated to the desired end temperature. The heater surfaces 206, 206′, 206″ and 206 ″ also consist of parallel-connected tubes. The superheated steam is fed through conduits 207, 207′, 207″ and 207‴, respectively, connected to the heater surfaces 206, 206′, 206″ 206‴, respectively, – after the four conduits 207, 207′, 207″, 207‴ respectively have been combined if desired — to a steam consumer (not shown). Each conduit 207, 207′, 207″, 207‴ contains a temperature measuring element with a signal transmitter 207, 208′, 208″, 208‴, respectively, which is connected by a signal line 209, 209′, 209″ and 209‴, respectively, to a regulator 210, 210′, 210″, 210‴, respectively, having a proportional-integral characteristic. Each of the regulators 210, 210′, 210″, 210‴ is connected by an adjusting signal line 211, 211′, 211″ and 211‴, respectively to a throttling element 212, 212′, 212″ and 212‴, respectively, disposed in an injection line 213, 213′, 213″ and 213‴, respectively, leading into the line 205, 205′, 205″ and 205‴, respectively, and supplying water for cooling the steam. Each of the conduits 213, 213′, 213″, 213‴ contains a restrictor 214, 214′, 214″ 214‴ connected by pressure lines 215, 215′, 215 and 215‴, respectively, to flow signal transmitters 216, 216′, 216″ and 216‴. The four injection lines 213, 213′, 213″, 213‴ are combined upstream of the restrictors and are fed by a common line 217.

From each of the flow signal transmitters 216, 216′, 216″, 216‴ a signal line 218, 218′, 218″ and 218‴, respectively, leads to a regulator 219, 219′, 219″ and 219‴, respectively, with a proportional-integral characteristic, the output of which is delivered by a signal line 220, 220′, 220″, 220‴, respectively, to the servomotor 221, 221′, 221″ and 221‴ of the throttling element 203, 203′, 203″ and 203‴, respectively. From each of the signal lines 218, 218′, 218″, 218‴ a signal line 222, 222′, 222″, and 222‴ leads to a unit 223, in which the arithmetic mean of the sum of the four flow signals is formed. The output signal of the unit 223 is connected by a signal line 224 to an addition point 225 from which a line 226 leads, which divides into four signal lines 227, 227′, 227″, 227‴, which in turn lead at 235, 235′, 235″ and 235‴, respectively, into the signal lines 218, 218′, 218″ and 218‴, respectively. From each of the signal lines 220, 220′, 220″, 220‴ a signal line 228, 228′, 228″, and 228‴, respectively, branches off and leads to a selector unit 228, in which the largest of the four adjusting signals delivered by the regulators 219, 219′, 219″ and 219‴ is selected and fed by a signal line 230 to a point 231 which also receives through a line 232 a desired value for the highest adjusting signal. The point 231 is connected to

the addition point 225 by way of a signal line 233.

With the regulating system shown in Figure 7, the flow of steam fed through the conduit 201 is divided among the four subsidiary conduits 202, 202′, 202″, 202‴ in such manner that the quantities of water supplied through the injection lines 213, 213′, 213″ and 213‴ are mutually equal, the said quantities of water in turn varying in dependence on the temperature of the steam emerging from the second superheaters.

Assuming that the throttling element 203 is fully open and there is a temperature increase at the heater surface 206′, the temperature increase of the steam is measured by the measuring device downstream of the heater surface 206′ and its impulse transmitter 208′ passes a signal through the line 209′ to the regulator 210′ which influences the throttling element 212′ in the injection line 213′ by way of the adjusting signal line 211′ in such manner that the throttling element opens so that a greater quantity of water is injected into the line 20′. This greater amount of water is detected by the restrictor 214′ so that the associated flow signal transmitter 216′ delivers a correspondingly larger signal to the line 218′. This larger flow signal reaches the unit 223 by way of the signal line 222′ branching off from the line 218′, and in the said unit 223 a larger signal representing the mean value is formed corresponding to the now larger sum, and is fed by the line 224 to the addition point 225 from which this mean value signal is fed as a desired value signal through the lines 227, 227′, 227″, 227‴ to the signal lines 218, 128′, 218″ and 218‴ at the points 235, 235′, 235″, and 235‴. A substraction between the regulated value and the desired value occurs in each case at the point 235, 235′, 235″, 235‴. The regulators 219, 219″ and 219‴ thus receive a reduced signal while the regulator 219′ receives a considerably larger signal than previously.

The servomotors 221, 221″ and 221‴ thus receive through each of the lines 220, 220″ and 220‴ smaller signals than previously, and they operate the throttling elements 203, 203″ and 203‴ respectively in such manner as to reduce their flow cross-section, whereas the flow cross-section of the throttling element 203′ is increased as a result of the larger signal acting on the servometer 221′. A smaller signal than previously — although still the largest in relation to the signals in the lines 228′, 228″ and 228‴ — is now fed through the signal line 228 to the selector unit 229, which accordingly delivers a smaller signal through the line 230 to the point 231. Since here the negative desired value signal in the line 232 predominates, a negative signal forms in the line 233 and causes a reduction of the desired value signal in the line 226. The reduced desired value signal is fed through the lines 227, 227′, 227″ and 228‴ and 218, 218′, 218″ and 218‴ to the regulators 219, 219′, 219″ and 219‴, so that in the signal lines 220, 220′, 220″ and 220‴ the signals are increased with the result that the throttling elements 203, 203″ and 203‴ are opened somewhat by means of the servomotors 221, 221″ and 221‴, while the throttling element 203′ is opened still further by means of the servomotor 221′. The opening movements of the throttling elements 203, 203″ and 203‴ thus compensates the previous closing movements so that these throttling elements return to their original flow cross-section. As a result of the larger flow cross-section of the throttling element 203′ than previously, the proportion of the total quantity of steam flowing through the subsidiary conduit 202′ increases so that the amount of water supplied by the injection line 213′ is reduced and mutually equal quantities of water now again flow through all the injection lines 213, 213′, 213″ and 213‴, the throttling element 203 again being fully open.

This regulating system gives the advantage that a smaller range of adjustment can be used at the throttling elements 212, 212′, 212″, 212‴, and hence a smaller quantity of injected water is sufficient than if the quantities of steam flowing through the subsidiary conduits 202, 202′, 202″, 202‴ were adjusted independently of one another. This advantage has a particularly favourable effect on thermodynamic efficiency. Moreover, the temperatures at the outlets of the heater surfaces 206, 206′, 206″, 206‴ are substantially equalised so that the material of the tubes can safely be subjected to greater thermal stresses than was hitherto permissible.

In another embodiment of the invention (not illustrated) the four injection water quantities are not added to form the mean value, but instead the total quantity of injection water flowing through the line 217 is measured and divided by four, similiar to the embodiment shown in Figure 2.

Instead of the continuous regulators in the exemplified embodiments described, it is possible to use non-continuous regulators or combinations of continuous and non-continuous regulators.

WHAT WE CLAIM IS:—

1. A regulating system for dividing a stream of fluid into at least two subsidiary streams in which each conduit carrying a subsidiary stream contains a throttling element with a regulator therefor and at least one of the throttling elements is always fully open, and in which there is fed to each

regulator a signal which is dependent on a regulated value that is in turn dependent on the flow of the associated subsidiary stream, and a desired value signal which is dependent in part on a desired proportion of the sum of the signals dependent on the regulated values and in part on an adjusting signal applied to the fully open throttling element from the associated regulator.

2. A regulating system as claimed in Claim 1, in which each subsidiary conduit is provided with a flow-measuring unit and a flow signal transmitter, which transmitters are connected by signal lines to a unit which forms the arithmetic mean of the sum of the flow signals and feeds the mean value to each regulator as a part of the desired value therefor, and a selector unit is provided the input of which is connected by signal lines to the output of each regulator and which selects from the adjusting signals delivered by all the regulators the one pertaining to the fully open throttling element, and, if the selected adjusting signal deviates from a desired value for that signal, feeds the deviation to each regulator as a further part of the desired value therefor.

3. A regulating system as claimed in Claim 1 in which each subsidiary conduit is provided with a flow-measuring unit and a flow signal transmitter, which transmitters are connected by signal lines to a unit by which it is possible to adjust different desired flow ratios for the subsidiary streams and which feeds to each regulator a signal corresponding to the proportion of the said adjusted ratio pertaining to the associated subsidiary stream, as a part of the desired value signal for that regulator, and a selector unit is provided the input of which is connected by signal lines to the output of each regulator and which selects from the adjusting signals delivered by all the regulators the one pertaining to the fully open throttling element, and, if the selected adjusting signal deviates from a desired value for that signal, feeds the deviation to each regulator as a further part of the desired value therefor.

4. A regulating system as claimed in Claim 1 in which each subsidiary conduit includes a heat-exchanger and, downstream of the heat-exchanger, a temperature-measuring element and a temperature signal transmitter, which transmitters are connected by signal lines to a unit which forms the arithmetic mean of the sum of the temperature signals and feeds the mean value to each regulator as a part of the desired value therefore, and a selector unit is provided the input of which is connected by signal lines to the output of each regulator and which selects from the adjusting signals delivered by all the regulators the one pertaining to the fully open throttling element, and, if the selected adjusting signal deviates from a desired value for that signal, feeds the deviation to each regulator as a further part of the desired value therefor.

5. A regulating system as claimed in Claim 1 in which each subsidiary conduit includes a heat-exchanger and, downstream of the heat-exchanger, a temperature-measuring element and a temperature signal transmitter, which transmitters are connected by signal lines to a unit by which it is possible to adjust different desired temperatures for the subsidiary streams and which feeds to each regulator a signal corresponding to the adjusted temperature of the associated subsidiary stream as a part of the desired value for that regulator, and a selector unit is provided the input of which is connected by signal lines to the output of each regulator and which selects from the adjusting signals delivered by all the regulators the one pertaining to the fully open throttling element, and, if the selected adjusting signal deviates from a desired value for that signal feeds the deviation to each regulator as a further part of the desired value therefor.

6. A regulating system according to Claim 1, in conjunction with a superheater section of a steam generator, in which each subsidiary conduit includes a first superheater heating surface and a second superheater heating surface; a water-injection line discharging in each case between the first and second superheater heating surfaces, a temperature-measuring element with a temperature-signal transmitter is provided in each case downstream of the second superheater heating surface and is connected in each case by a signal line to a regulator influencing the quantity of water injected, each water injection line contains a flow-measuring element with a flow signal transmitter which are connected by signal lines to a unit which forms the arithmetic mean of the sum of the injection quantity signals and feeds the mean value to each regulator of the subsidiary conduits through which stream flows as a part of the desired value for that regulator, and a selector element is provided the input of which is connected by signal lines to the output of each regulator of the subsidiary conduits through which stream flows and which selects from the adjusting signals delivered by all the regulators the one pertaining to the fully open throttling element, and, if the selected adjusting signal deviates from a desired value for that signal, feeds the deviation to each regulator of the subsidiary conduits through which the steam flows as a further part of the desired value for that regulator.

7. A regulating system for dividing a stream of fluid into at least two subsidiary streams, substantially as described with

reference to any of Figures 1, 2, 3 or 7, or to Figure 4 without, or with either of or both, the modifications shown in Figures 5 and 6, of the accompanying diagrammatic drawings.

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Chartered Patent Agents,
Agents for the Applicants.

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Fig.1

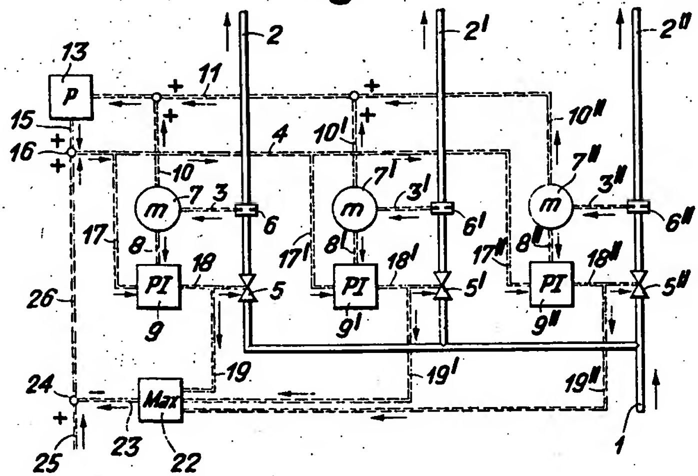

Fig.2

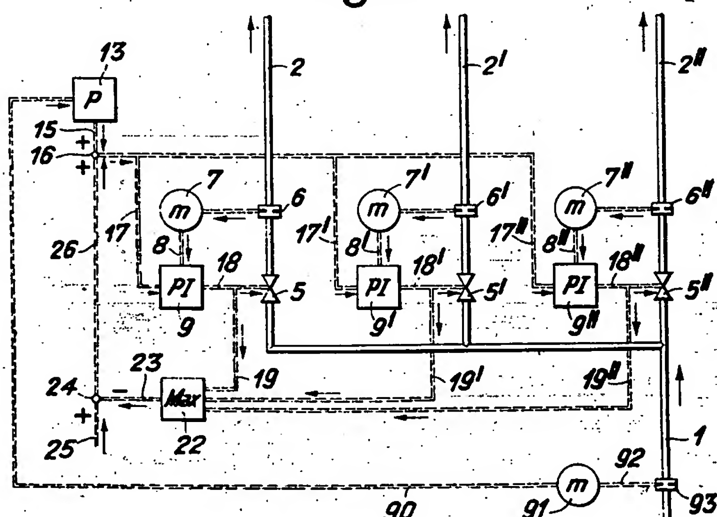

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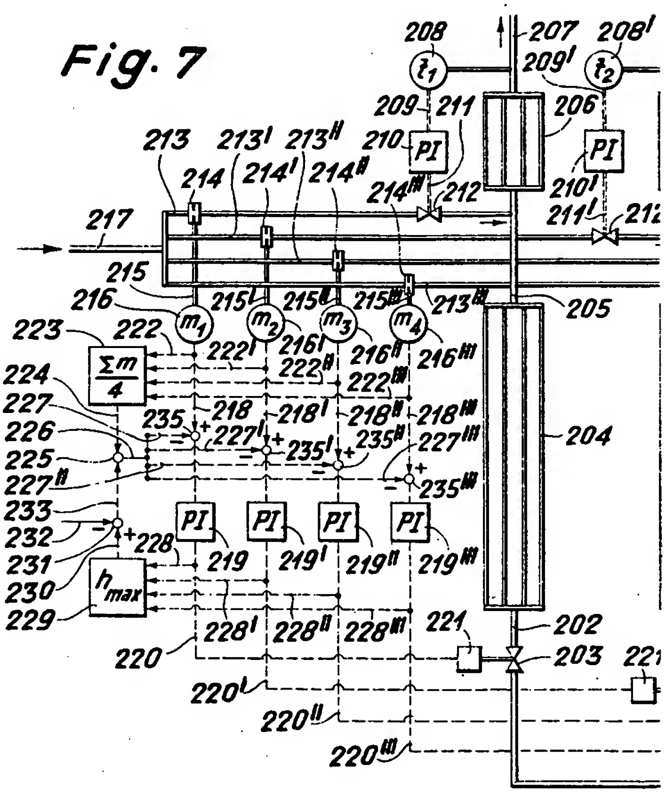
Fig. 7



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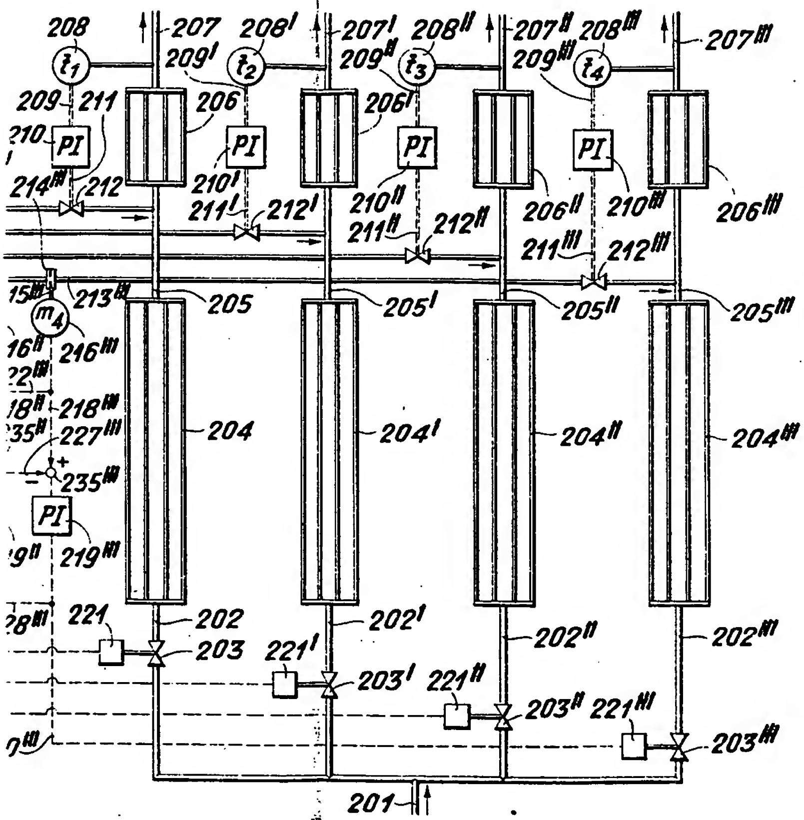
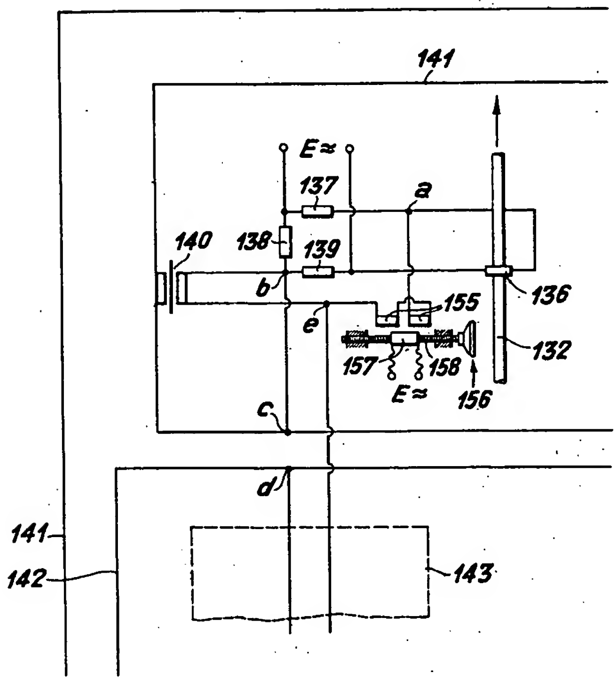


Fig. 5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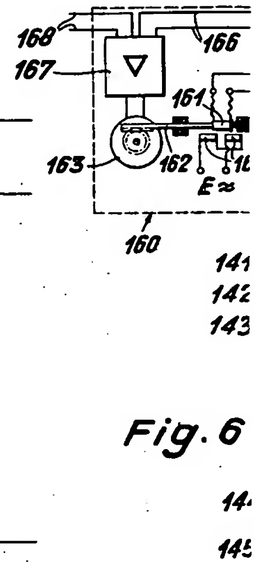
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Fig. 6

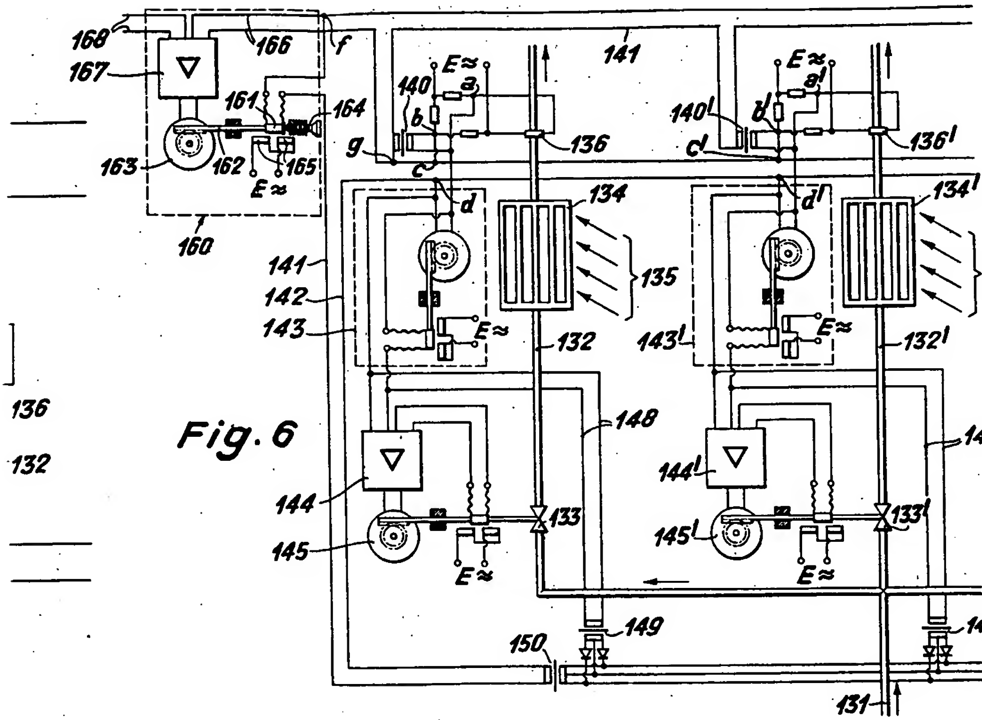
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Fig. 6

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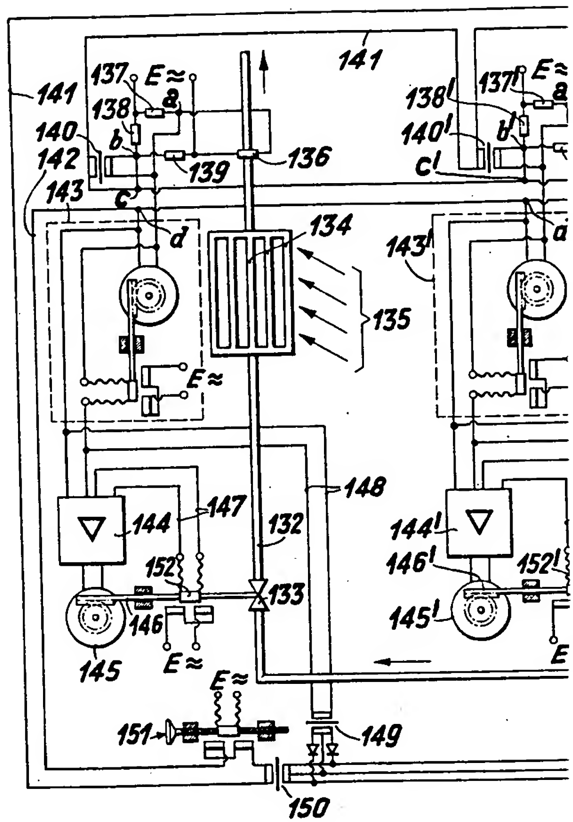

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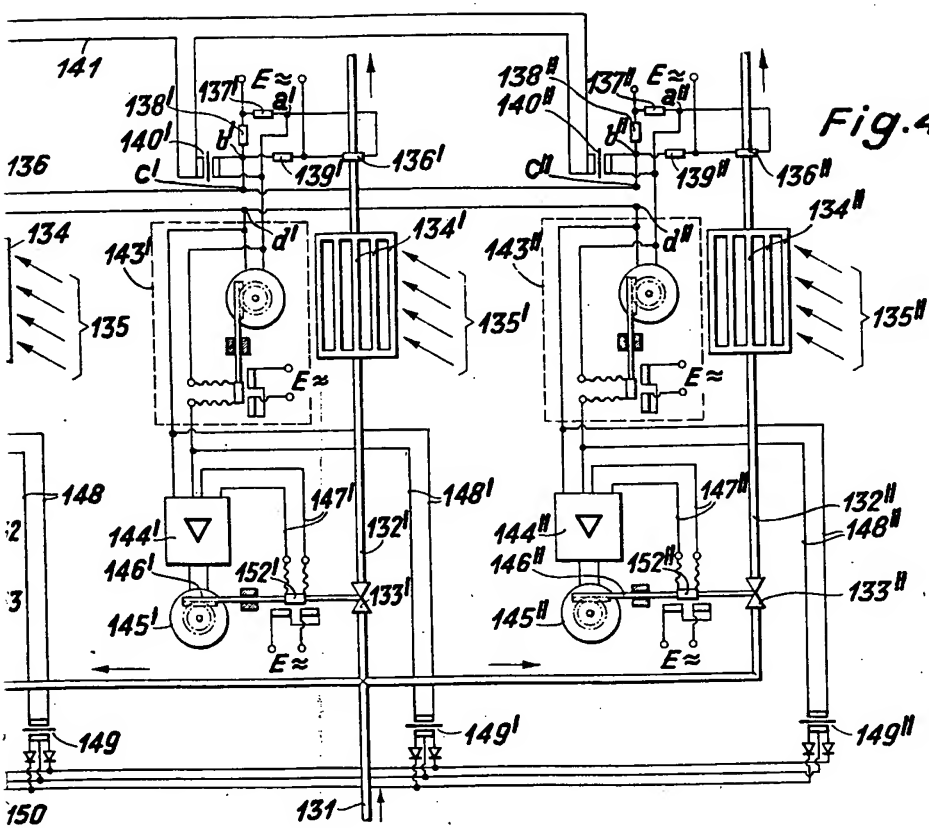

Fig.4

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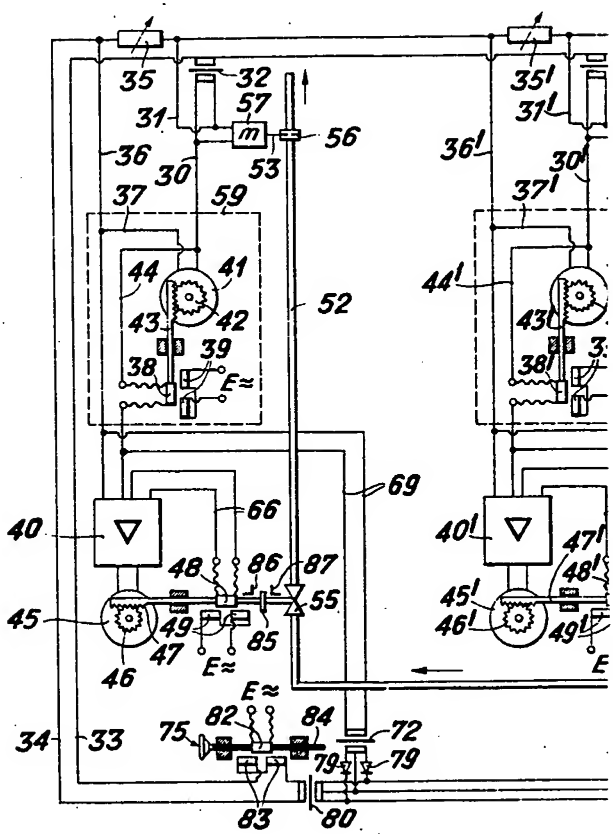

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